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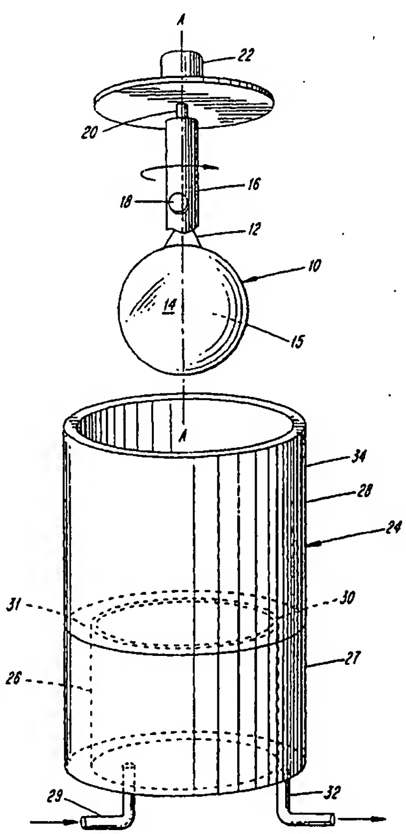
(54) Title: SPIN COATING TECHNIQUES



(57) Abstract: A lens element with a radially extending tab may be hard coated on both sides thereof. Method and apparatus are disclosed for holding the lens element in a chuck. While holding the lens element in the chuck (16), successive steps are performed on the lens element including cleaning the lens element, applying a fluid hard coat to the lens element, spinning the lens element about a vertical axis (A-A), and performing a curing step at a curing station.

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Minimum documentation searched (classification system followed by classification symbols)
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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 376 408 A (LIPPERT THOMAS M) 27 December 1994 (1994-12-27) cited in the application	
A	US 5 685 908 A (FARLEY EMANUEL DEAN ET AL) 11 November 1997 (1997-11-11) cited in the application	
A	US 5 820 673 A (SENTILLES J BRUCE ET AL) 13 October 1998 (1998-10-13) cited in the application	
A	US 5 843 527 A (SANADA MASAKAZU) 1 December 1998 (1998-12-01) cited in the application	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"TERNATIONAL SEARCH REPORT

Information on patent family members

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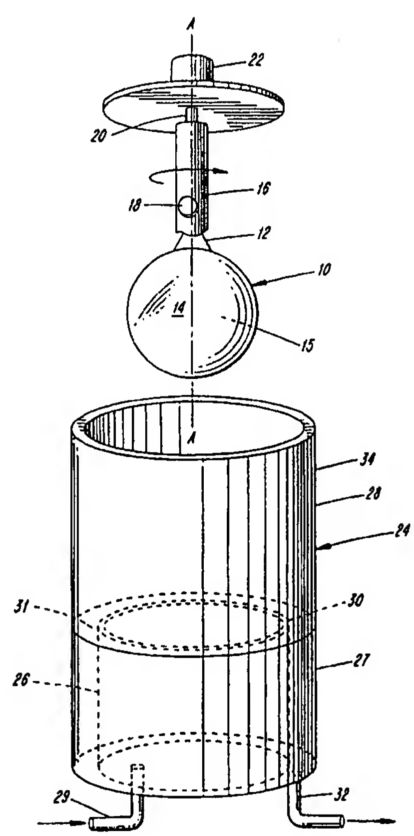
(54) Title: SPIN COATING TECHNIQUES



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SPIN COATING TECHNIQUES

FIELD OF THE INVENTION

The present invention relates to techniques for spin coating optical bodies, and especially to applying and curing hard coatings on molded plastic lens elements.

BACKGROUND

Ophthalmic lenses such as for corrective eyewear, sunglasses and goggles are often made from plastic. The plastics include, for example, polymers based on allyl diglycolcarbonate monomers and polycarbonates. The lenses may be formed as a single integral body or as laminated lenses formed by bonding lens wafers together with a transparent adhesive. Such laminated lenses are described for example, in U.S. Patent Nos. 5,149,181; 4,857,553 and 4,645,317. Finished lenses are typically made by edging lens blanks. The term "ophthalmic lens element" may include, according to context, finished or edged ophthalmic lenses, semi finished lenses, lens blanks or wafers for forming laminated lenses or laminated lens blanks.

Plastic lenses, particularly those manufactured of polycarbonate are susceptible to scratching and abrasion. It is known to apply ultra-violet cured acrylic hard coatings to polycarbonate lenses to provide a more scratch and abrasion resistant coating. Such coatings are described, for example, in Applicant's U.S. Patent No. 5,949,518 to Belmares *et al.,* which is hereby incorporated by reference.

Typically, the hard coating is applied by dipping batches of lenses in hard coating solutions and then curing the coating. While such processes are relatively efficient, it is difficult to control the uniformity, quality and yield of the coated lens elements.

It has been proposed in the prior art to spin coat lens to apply coatings. *See*, for example, U.S. Patent Nos. 5,959,518; 5,843,527; 5,820,673 and 5,685,908 and WO 94/14544.

Conventional spin coating of plastic lens elements employs gripper type chucks to hold the lens element on its perimeter for spinning the lens element in a horizontal plane. Alternatively, vacuum chucks such as the vacuum lens cup employed in above-mentioned U.S. patent No. 5,820,673 are employed to grip one side or optical surface of the lens element for spinning. Such chucks have relatively complex construction and may be difficult to load and unload. If the lens element is held by the chuck during curing, it may interfere with UV exposure because portions or even an entire side of the lens will be shaded or shadowed by the chuck. Moreover, resin build up on the grippers may further interfere with producing a uniform coating. If each side of the lens element is separately coated with vacuum chucks, the chucks often leave marks or scratches on the coated product. The additional handling reduces efficiency and yield.

Accordingly, it is a primary object of the present invention to provide improved methods and apparatus for applying coatings to plastic lens elements.

It is a further object of the present invention to provide efficient and inexpensively implemented techniques for processing plastic lens elements during the application and curing of hard coatings.

It is a further object of the present invention to provide plastic lens elements with a substantially uniform hard coating applied to both sides without marks or scratches in the coated lens element.

It is a further object of the present invention to provide improved uniformity and yield in hard coating plastic lenses.

These and other objects and advantages will be apparent from the following text and drawings.

SUMMARY OF THE INVENTION

The present invention includes methods and apparatus for providing a uniform coating on a lens element by spin coating without the above-noted disadvantages of processes using conventional chucks and holding fixtures. In accordance with preferred embodiments of the invention the lens is held by gripping a member integrally formed at a radial edge of the lens such as a molding sprue or runner. Unlike conventional dip processing however, wherein the coating film is controlled by a slow and steady withdrawal from the resin, in accordance with the present invention, the lens is rapidly spun about a vertical axis after the coating fluid is applied by dipping or spraying. The result is a novel lens element of a preferred embodiment of the present invention with an unmarred coating on both principle surfaces.

One aspect of the present invention is an integrated apparatus for applying a coating to plastic lens elements and curing the coating in one operation without loading or unloading the lens elements between the steps. The apparatus includes a chuck for holding a member protruding from a radial edge of each lens element. A coating applying station includes a supply of liquid coating fluid. A full curing station, such as a UV light box or a precure (tack free) heat curing station is located nearby. A conveyor and spindle assembly positions the chuck for precleaning and subsequent contacting of the lens element with coating fluid from the supply. After coating fluid is placed on the lens element, the lens element is spun about a vertical axis thereof to remove excess coating solution and to form a film of the required thickness. The chuck is then moved so that the lens element is positioned to be exposed to a curing treatment at the UV curing station or, alternatively, to precure thermal resins at the heat station. The apparatus may also include one or more cleaning and drying stations for preparing the lens element for application of the coating.

In preferred embodiments the chuck grips a sprue which is integrally molded with the lens element and which extends from the radial edge of the lens element adjacent an optical surface of the lens element.

In another preferred embodiment, the lens element is contacted with hard coating fluid by spraying the lens element with the fluid or dipping the lens element into a reservoir of coating fluid. The contacting may be performed by lowering the chuck so that the lens element is positioned in the spray chamber or reservoir. Alternatively, the resin source may be raised into proximity of the lens element for resin application. When the lens element has been contacted with liquid coating solution, it may be moved by the chuck or conveyor into a spinning chamber where it is spun to remove excess coating solution and form the film of required thickness.

In a preferred embodiment the lens element is coated with an organic coating formed from a hard coating fluid. The hard coating may be a UV cured acrylate (but may also be, for example, a UV cured thiolene, urethane or urethane-acrylate). In fluid form the coating may have a viscosity of 5 to 20 centipoise and be spun at 1000 to 3000 RPM for 3 to 20 seconds. The resulting coating may be 2 to 10 microns in thickness.

Alternatively, thermally cured coatings may be applied with the spin coating techniques of the present invention. The coating may be, for example, thermally cured urethanes, thiolenes or polysiloxane sol-gel systems. The spin coating techniques of the present invention could also be used to apply UV cured, thermally cured or air dried urethane or thiolene primer coatings.

The thermally cured coatings may be somewhat thinner than the UV cured coatings described above. The primer coatings may be from 250 nm to 2μm in thickness. A top "hard" coating could be applied over a primer coating and this could add 2 to 10 microns of coating thickness. Where multiple spin coatings are applied to one or both of the lens element surfaces, some, and preferably all, the

coatings may be applied by the vertical spin coating techniques of the present invention.

The present invention also includes methods for applying a cured hard coat on both sides of an ophthalmic lens element. In such methods a reservoir of hard coat fluid is provided. A lens element is suspended from a work holder which engages a radially extending tab portion of the lens element. A hard coat fluid is applied to both sides of the lens element. The work holder and the lens element are then spun about a vertical axis to remove excess hard coat fluid and form a coating of the desired thickness on both sides of the lens element. While continuing to suspend the lens element from the work holder, the lens element is exposed to a curing treatment to cure the hard coat, or to effect precure in the case of thermally cured resins.

In a particularly preferred embodiment, a reservoir or spray chamber is raised into proximity of the lens element to apply coating fluid to both sides of the lens element. The reservoir or spray chamber is then lowered to place the lens element in a spin chamber where it is spun to remove excess hard coat fluid, the excess being collected on walls on the chamber for recirculation.

These and other objects and features will be apparent from the following summary and descriptions of preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a pictorial view of an apparatus employed in a preferred embodiment of the present invention;

Figures 2(a) through 2(d) and 3(a) through 3(d) illustrate sequential steps in a method for coating a lens element and curing the coating and the apparatus used therein, all in accordance with preferred embodiments of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 is a pictorial view of an apparatus for spin coating a workpiece in accordance with teachings of a preferred embodiment of the present invention. A lens element 10 such as a plastic lens blank is formed with a member, runner, sprue or tab 12 extending from a radial edge of front and back principal optical surfaces 14 and 15 to be coated. The member 12 is inserted into a chuck 16. The member 12 may be gripped in place by a thumb screw or other suitable gripper 18 as shown. Alternatively, a zero insertion force sprue holder, spring holder, or vacuum gripper may be used. In a preferred embodiment, the chuck may be remotely engaged and disengaged by a remote control for automatic loading and unloading, or actuated with a foot switch actuated by a loading operator.

The chuck 16 is supported by a shaft or spindle 20 for rotation about a substantially vertical axis A-A. A motor 22 is provided to rotate the shaft, chuck and lens element.

Coating is applied to both optical surfaces of the lens element in the application vessel 24. In a preferred embodiment of the present invention, the application vessel consists of a reservoir or inner dip cup 26 for hard coating fluid located within a containment vessel 27. A spinning chamber 28 of the containment vessel is also provided in proximity of the reservoir or dip cup. Hard coating fluid is introduced into the reservoir 26 through inlet 29. A weir formed by the lip edge 30 provides a fluid level control and a continuous overflow of hard coating fluid which exits the containment vessel 27 through outlet conduit 32. It will be understood that this system maintains a substantially constant fluid level at the height of the weir. The depth of the inner dip cup 26 is selected to permit complete immersion of the lens element in the fluid.

In preferred embodiments the hard coating fluid is a polymerizable mixture of resins and solvents. A preferred fluid may be an ultra violet light polymerizable compound. Alternatively, the hard coating fluid may be composed of a

thermosetting resin composite containing a thermal polymerization initiator. More preferably, the hard coating agent is a photo curable resin composition containing a photo polymerization initiator, and, in particular, an ultra-violet ray curable resin composition. Advantageously the hard coat fluid has a viscosity range of from 2 to 20 centipoise.

In operation of one preferred embodiment, the application vessel 24 is raised to immerse the lens element 10 in hard coating fluid. Alternatively, the lens element and chuck are lowered into a stationary application vessel. In either case advantageously the chuck does not contact the fluid and, thus, does not experience resin build up or provide a source of unwanted dripping or shedding of hard coating fluid. After the lens element has been immersed for a short time in the fluid in the reservoir, the reservoir is lowered to place the lens element in the spinning chamber 28. Alternatively, positioning in the spinning chamber is accomplished by raising the chuck 16 and spindle 20.

In the spinning chamber the chuck 12 and lens element 10 are rotated about axis A-A at, for example, 1000 to 3000 rpm for 5 to 20 seconds. Centrifugal force causes the excess hard coating fluid to be flung toward the cylindrical wall 34 of the spinning chamber 28 where it runs down and is collected in the containment vessel 27. The fluid may be withdrawn through outlet 32, filtered and recirculated in the system to inlet 29.

Surface wetting produces a generally uniform hard coating thickness across the surface of the lens. In a preferred embodiment, the final thickness of the hard coating may be between 1 and 20 microns and more typically between 2 and 8 microns. The thickness of the hard coating may be selected depending on the end use application and the degree of abrasion resistance desired. Primer coatings of 250 nm to 1 μm in thickness may also be applied using the spin coating techniques of the present invention.

Figures 2 and 3 are schematic diagrams in partial cross section, illustrating a preferred processing sequence for hard coating a lens element on a manufacturing

line. The components of the illustrated manufacturing line include a work holder and spindle assembly 100, an ultrasonic cleaning station 102, a coating application vessel 104 and curing station 106. The components may be contained in a clean environment, for example a HEPA type enclosure.

A lens element 108 is illustrated in successive stages in the processing in Figures 2 and 3. The lens element 108 is held by a chuck 110 in the manner discussed in connection with Figure 1. A conveyor 112 is provided to move the lens element 108 and work holder from station to station during processing. The conveyor also is capable of moving the lens element and work holder up and down to position the lens element at each station as will be described below. Alternatively, the various stations may be moved up and down to lens elements maintained at a fixed height. The relative vertical movement of the lens holder and stations is indicated in Figures 2 and 3 with respect to the reference bar 114. In the illustrated embodiment the lens element and work holder have three working positions: "up", "middle" and "down". Where a three inch lens blank is being processed, the vertical distance between the "up" and "down" position is at least six inches. Though the embodiment of Figures 2 and 3 operates to move the lens element vertically, it will be understood that the apparatus can be configured such that the lens element remains at a fixed height and the various stations can be moved vertically to achieve the indicated relative positioning.

At Figure 2(a) the lens element is shown at a loading station *i.e.* just prior to insertion of the radially extending tab 116 into the chuck 110. In Figure 2(b) the work holder and lens element have been conveyed and lowered into the cleaning station 102, where the lens element is cleaned prior to coating. A cover 120 carried by the work holder may be provided to contain the cleaning operations.

In Figure 2(c) the cleaned lens element is shown being conveyed to the coating application vessel 104. During this travel the work holder may be in the "up" position as shown. In Figure 2(d) the lens element has been lowered into the portion 122 of the application vessel 104 where hard coating fluid is first applied.

The application vessel may be of the reservoir type as described in connection with Figure 1. Alternatively, as shown in Figure 2(d) the coating may be applied by spray jets 124.

The next step in the process at this station is illustrated at Figure 3(a). After the initial application of hard coating fluid, the lens element may be raised into the "middle" position so that it is positioned in the spinning chamber 126. Here, a motor 128 is actuated to spin the lens element about vertical axis A-A. Excess fluid is thrown toward the walls of the spinning chamber as shown and collected in the channel formed by the lip 127 and weir 129. The cover 120 helps to contain the fluid. When spinning is complete, the lens element is raised out of the spinning chamber 126 to the "up" position and transported to the curing station as shown at Figure 3(b). When it reaches the curing station it is lowered into the curing station 106 through chimney 130.

The curing station may be a heating station in the case that the hard coating fluid contains a thermo polymerization agent. As depicted in Figure 3(c), however, the curing station provides UV photo polymerization. In the curing station 106, the lens element is exposed from essentially all angles to incident UV light. The UV light may be generated by a mercury tube 132 excited by a magneton 134, having a power output of 1200 to 1800 watts. The interior of the curing station 106 is lined with an aluminum reflecting material (ALZAK) which essentially eliminates shadowing of the lens element during UV exposure. The cover 120 contains the UV light and prevents unwanted leakage into the production line area. A typical exposure time is 10 seconds after which the magnetron is powered down and the lens element is raised out of the curing station. The hard coated lens may then be unloaded at an unloading station as indicted at Figure 3(d).

Accordingly, an efficient and well controlled process is provided for rapidly applying and curing a hard coating on plastic lens elements.

The present invention has been described in connection with various embodiments and examples. However, the invention to be protected is defined by the following claims and equivalents thereof.

I CLAIM:

1. Apparatus for applying a coating to a plastic lens element and curing the coating, comprising:

a chuck for holding a member protruding from a radial edge of the lens element;

a supply of liquid coating fluid;

a curing station; and

means for effecting relative movement between the chuck and the supply to contact the lens element with liquid coating fluid from the supply, for spinning the lens element about a vertical axis thereof to remove excess coating fluid and form a coating of substantially uniform thickness on an optical surface of the lens element, and for positioning the lens element for exposure to a curing treatment at the curing station.

2. The apparatus of claim 1 wherein the chuck grips a molding sprue which is integral with and extends from the radial edge of the lens element adjacent an edge of an optical surface of the lens element.

3. The apparatus of claim 1, wherein the liquid coating is a UV cured hard coating fluid.

4. The apparatus of claim 3, wherein the curing station is a UV light box.

5. The apparatus of claim 1 wherein the liquid coating solution is a thermally cured hard coat fluid and

wherein the lens element is thermally precured to a tack free state at the curing station.

6. The apparatus of claim 1 wherein the liquid coating solution is a curable primer coating.

7. The apparatus of claim 1, wherein the lens element is contacted with liquid coating fluid by spraying the lens element with coating fluid.

8. The apparatus of claim 1, wherein the lens element is contacted with liquid coating fluid by dipping the lens element in a reservoir of coating fluid.

9. The apparatus of claim 1, wherein the lens element is contacted with liquid coating fluid in a lower portion of an application vessel after which the application vessel is lowered to position the lens element in a spinning chamber where it is spun to produce a coating film of desired thickness.

10. The apparatus of claim 1, wherein the lens element is contacted with liquid coating fluid and raised upward into a spinning chamber where it is spun to produce a coating film of desired thickness.

11. The apparatus of claim 1, wherein the lens element is spun at 1000 to 3000 RPM for 5 to 20 seconds.

12. The apparatus of claim 1, wherein the applied coating is UV cured organic coating from 2 to 10 microns in thickness.

13. The apparatus of claim 12, wherein the coating fluid in the supply is an acrylate with a viscosity of 5 to 20 centipoise.

14. The apparatus of claim 1 wherein the applied coating is a primer coating with a thickness of 250 nm to 2 μm.

15. The apparatus of claim 1, further comprising a cleaning station, and wherein the positioning means includes a conveyor to position the chuck at the cleaning station prior to applying the coating.

16. The apparatus of claim 1, further comprising an ultrasonic cleaning station and wherein the positioning means includes a conveyor to position the chuck at the cleaning station prior to applying the coating.

17. A method for applying a cured hard coat on both sides of an ophthalmic lens element comprising:

providing a reservoir of hard coat fluid;

suspending a lens element from a work holder which engages a radially extending tab portion of the lens element;

applying a hard coat fluid to both sides of the lens element;

spinning the work holder and the lens element about a vertical axis to remove excess hard coat fluid and to form a coating of approximately uniform thickness on both sides of the lens element; and

while continuing to suspend the lens element from the work holder, conveying the lens element to a curing station and exposing the lens element to a curing treatment.

18. The method of claim 17, wherein the lens element is a molded polycarbonate lens element and the tab portion is integrally molded with optical portions of the lens element.

19. The method of claim 17, wherein the lens is spun at 1000 to 3000 RPM to form a coating of from 2 to 10 microns in thickness.

20. The method of claim 17, wherein the lens element is exposed to UV radiation to cure the hard coat.

21. The method of claim 17, wherein the lens element and a hard coat fluid reservoir are moved relative to one another to dip the lens element in the reservoir to apply coating fluid to both sides of the lens element.

22. The method of claim 21, wherein the lens element is positioned in a chamber where it is spun to remove excess hard coat fluid, the excess being collected on walls of the chamber for recirculation.

23. The method of claim 17, further comprising cleaning and drying the lens element prior to applying the hard coat fluid.

24. A lens element made by the method of claim 15.

25. Apparatus for coating a molded optical body comprising:

a work holder for releasably engaging a radially extending tab portion of the molded optical body;

a chamber in which coating is applied to the optical body;

a spinning chamber in which the work holder and optical body are spun about a vertical axis; and

means for sequentially positioning the optical body in the coating chamber and then in the spinning chamber.

26. The apparatus of claim 25, further comprising a curing chamber, wherein the conveyor moves the work holder and optical body to position the optical body in the curing chamber.

27. The apparatus of claim 25, further comprising a cleaning and drying station, wherein the conveyor moves the work holder and optical body to position the optical body for cleaning and drying prior to applying the coating.

28. The apparatus of claim 25, wherein the coating chamber and spinning chamber are formed in a single vessel and wherein the spinning chamber is located above and connected to the coating chamber.

29. The apparatus of claim 28, wherein the positioning means includes means for lowering the vessel to move the optical body from the coating chamber to the spinning chamber.

30. The apparatus of claim 25, wherein the positioning means includes a conveyor for positioning the optical body over the vessel, lowering the optical body through the spinning chamber into the coating chamber where coating is applied and raising the optical body into the spinning chamber for spinning.

31. A lens element comprising:

a molded plastic body having two principle optical surfaces and an integrally molded, radially extending member adapted to be gripped by a work holder; and

a coating simultaneously applied to both optical surfaces by applying coating fluid to both sides of the lens element while the member is gripped and spinning the work holder and the lens element about a substantially vertical axis.

32. The lens element of claim 31, wherein the coating is a cured organic hard coating.

33. The lens element of claim 32 wherein the plastic body is polycarbonate and the hard coating is a UV cured coating of from 2 to 10 microns in thickness composed of a material selected from the group of acrylate, thiolene, urethane or urethane-acrylate hard coatings.

34. The lens element of claim 31 wherein the coating is a thermally cured coating selected from the group of urethane, thiolene or polysiloxane sol-gel systems.

35. The lens element of claim 31 wherein the coating is a cured primer coating of from 250 nm to 2 microns in thickness composed of a material selected from the group of urethane and thiolene primer coatings.

Fig. 1

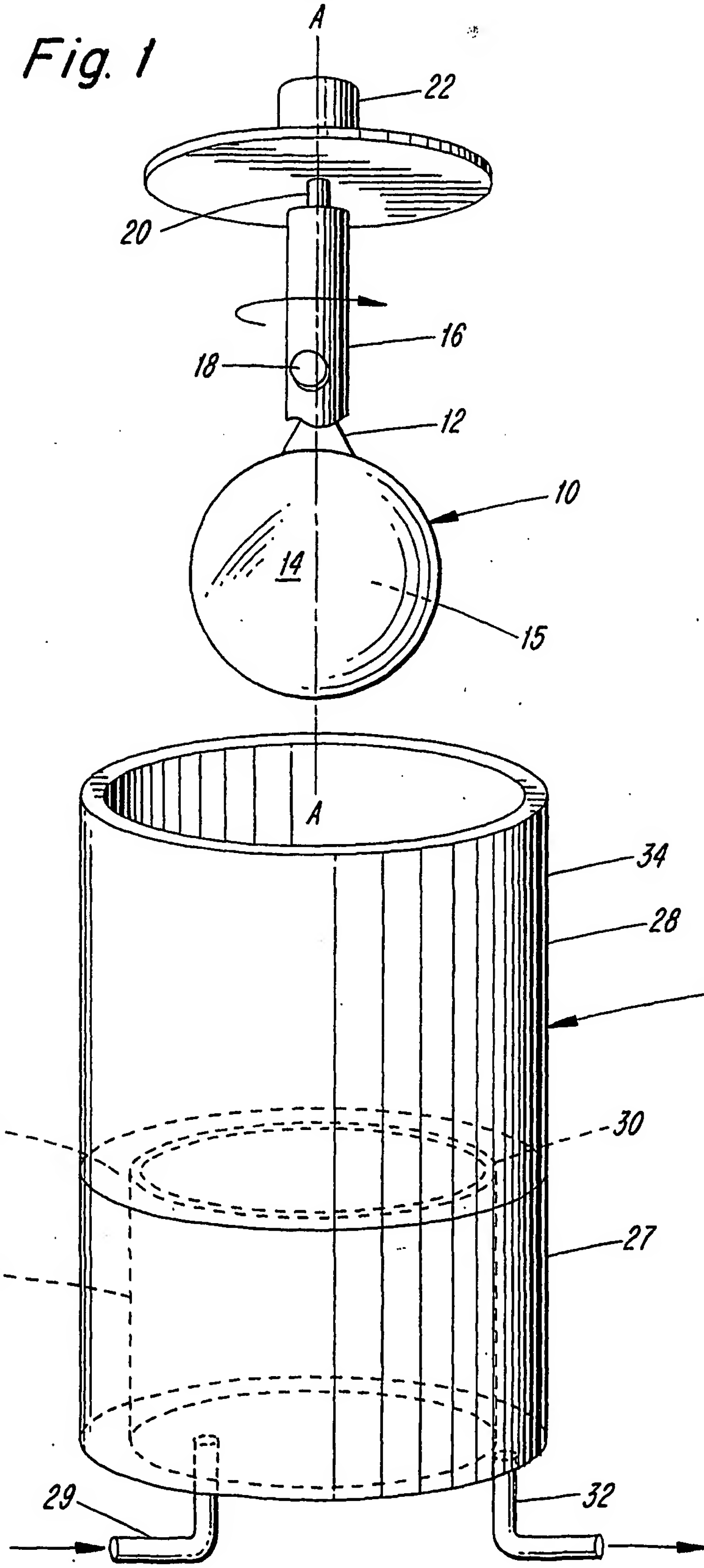
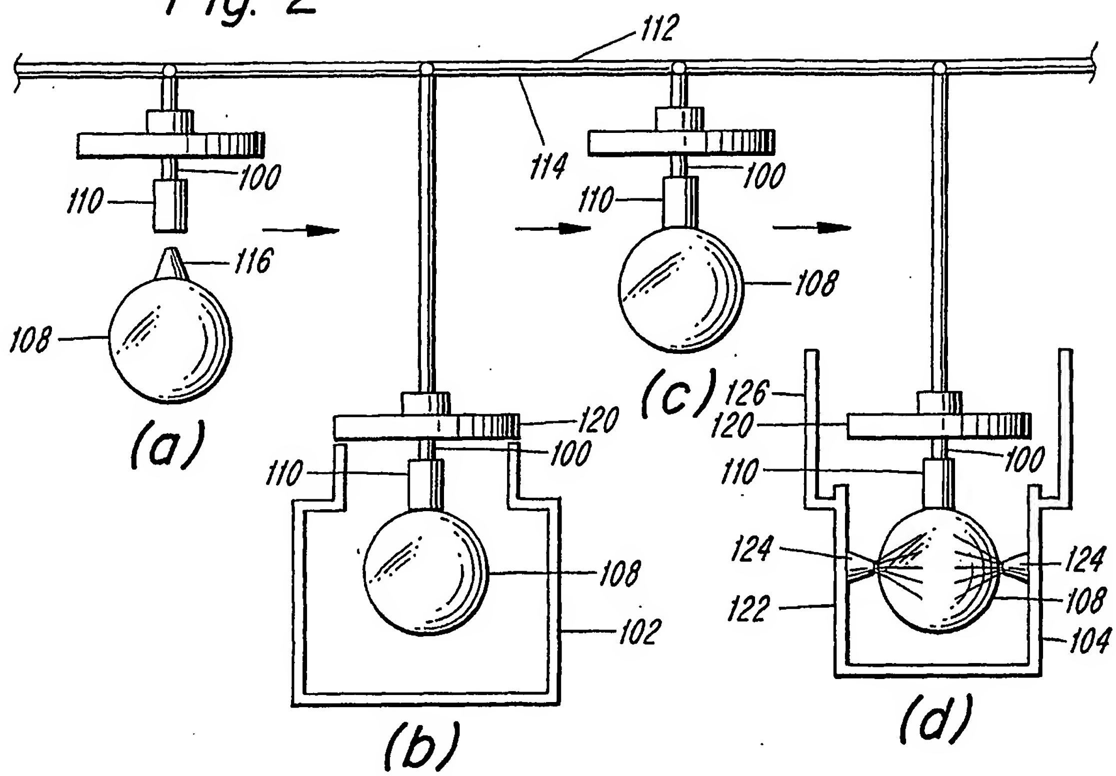


Fig. 2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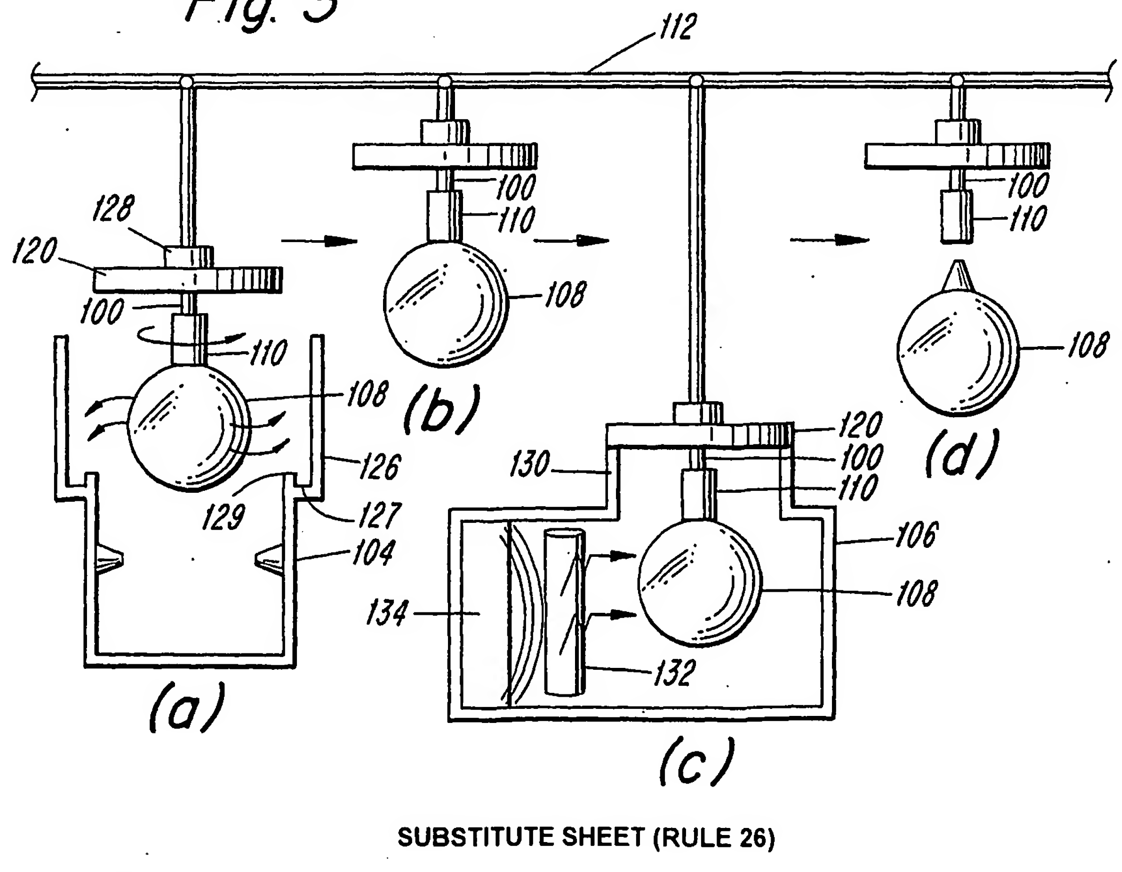
124
124
108
122
104
(d)

Fig. 3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